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DESIGNING ON-CONDITION TASKS FOR NAVAL AIRCRAFT

LEVEL II

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I. INTRODUCTION

This handbook has been prepared to sharpen your knowledge about designing and applying "On Condition" maintenance tasks to Naval aircraft.

If you're turned on by the opportunity to be an expert in aircraft maintenance, what follows was written just for you. Use it as a key for using what you've already learned to improve the quality of preventive maintenance. Use it to select new tasks that will prevent functional failures, to replace inefficient, hard-time tasks that waste labor, time and materials, or to eliminate phony "On Condition" tasks that soak up labor and time but do not prevent failures.

PREVENTIVE MAINTENANCE PROCESSES

All of us believe in preventive maintenance. In our own lives, for our own property, we each make decisions about the need for preventive maintenance. However, lacking precise information about the effectiveness of our decisions, each of us has rather different ideas about which things require preventive maintenance and about the effectiveness of certain tasks. We also have different answers to the question, "What is a failure?"

All useful things are intended to provide some function.* This function may be active or passive and it may be continous, periodic or random. It may also be either evident to the user or hidden from him. In complex systems there may be subfunctions, or even sub-subfunctions that serve the system itself by controlling it or protecting it in a way not evident to the user.

At any instant, on demand, an intended function is either available or unavailable. We call this unavailability "failure". We dislike failures for a number of reasons. Some are threats to life, limb or property; some simply deprive us of a utility for which we

* For example, the functions of a landing gear include absorbing landing shocks and supporting the aircraft on the ground.

have paid; others do not affect us immediately but increase the risk of more serious failures at some future time.

Although we have broad differences in our beliefs about the application of preventive maintenance in our personal lives, we can probably agree on the nature of the choices that we make. Now, let's consider your own ideas. Once you have given some thought to the possibility of preventing some failure you will discover that you have three alternatives:

A. Do some specific task periodically without considering the conditions existing at the time. An example would be to replace all the spark plugs in your car's engine every 10,000 miles.

B. Do some specific task periodically that compares observed conditions at the time with a pre-determined standard. An example would be to remove each spark plug from your car's engine, measure the gap, adjust it to .025", and check the insulator for cracks and carbon tracks.

C. Do nothing until failure occurs. An example would be to change, or adjust and clean, spark plugs only when the engine does not start easily or runs rough under heavy loads.

These same ideas apply to aircraft, as they do to all useful things. In fact, because of the fragile, non-redundant nature of early airplanes, a careful, detailed inspection by the pilot was a routine, pre-flight event. However, any reading of aviation history will reveal that, nevertheless, many failures occurred. As knowledge increased about what failures were most likely to occur, additional preventive tasks were applied. Some of these were very effective. Some were not.

In commercial transport aviation, under government regulation there was, for a long time, a growing reliance on scheduled overhaul of the airframe, engine(s) and other equipment as a means for ensuring flight safety. The intensity of this practice increased until shortly after World War II. Until then, the mainte-

nance process had grown up "in the shop". In many cases, an airline's fleet was so small that the mechanics had unique knowledge about each airplane that had a strong influence on their day-to-day maintenance decisions. There was no particular interest in obtaining data about the mechanical performance from all the airplanes in the fleet for the purpose of analysis. The idea of using such information collectively to improve the effectiveness of the maintenance process did not yet attract much interest.

Once such analysis began it revealed that the preventive maintenance tasks developed "in the shop" were not always as effective when applied generally as they were when the assigned mechanic also had a great deal of specific knowledge about a specific engine or airframe. In many cases, by using failure data in the same way that life insurance companies use birth and death data, analysts eventually found that such data clearly showed that, except for "servicing" tasks, reliability was not affected by imposing a so-called preventive task.

By now, we've identified three different alternatives, if we are considering a preventive maintenance task:

A hard time task (HT)

An on condition task (OC)

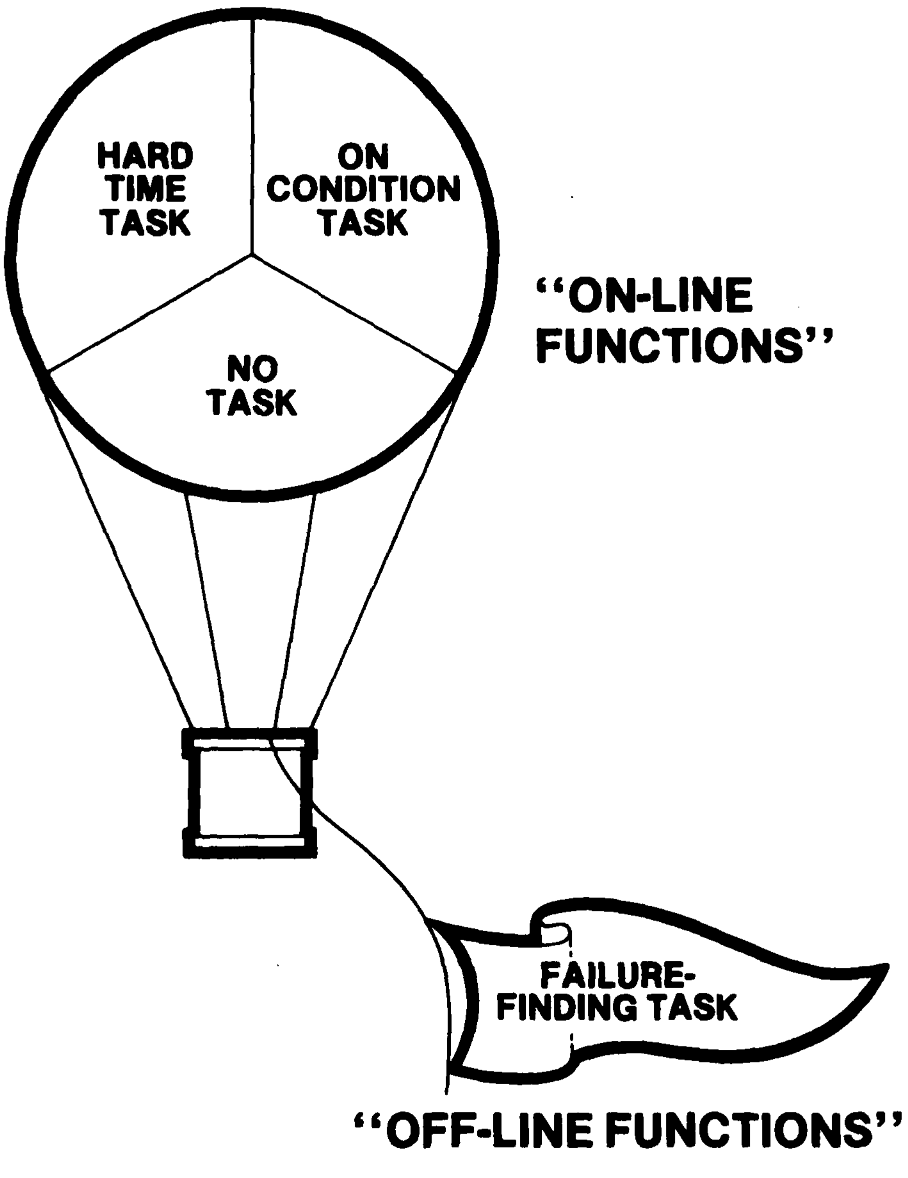
No task at all

So far, in this review of the history of preventive maintenance we've focused on the tasks intended to prevent failures, failures that are evident to the user during operations. Earlier, you will recall that *hidden* functions were briefly mentioned. These may require a different kind of task — tasks that are periodically done to discover whether such functions are available. (The task that checks the alternative way of dropping the landing gear is a good example.) These are similar to the other tasks related to hardware condition, but they are intended to discover failures, not prevent them. These are called "failure-finding tasks" (FF).

Lets look at a picture that represents these ideas:

FIGURE 1

MAINTENANCE TASK ALTERNATIVES



A HISTORY OF THE "ON-CONDITION" MAINTENANCE PROCESS

The first formal recognition by the Federal Government of a maintenance process different from periodic overhaul or replacement occurred in 1947. At that time, the airlines recommended that, instead of scheduling certain maintenance actions solely on the basis of flight time, these actions should be based *on condition*. This process is now called "On-Condition" maintenance throughout the aviation community.

Initially, this process (often identified by the letters OC) applied only to a very limited group of items — tires, brakes, control surface fabric and various cabin equipment items, for example.

The original rules for applying "On-Condition" maintenance required that it be restricted to:

> "...components on which a determination of continued airworthiness may be made by visual inspection, measurement, tests or other means without a teardown inspection or overhaul"

In practice, for non-critical equipment such a cabin equipment, these requirements were rather loosely applied. *Note* however that the C.A.A. (now F.A.A.) continued to show its preference for hard time overhauls by stating:

> "If an item or appliance cannot be maintained in a condition of continued airworthiness in accord with the proposed procedures, it must have an overhaul time affixed which is well within its expected airworthy life."

You can see that new ideas in any environment lead a hard life.

Having obtained approval of "On-Condition" maintenance as an acceptable process, the air transportation community soon

recognized the breadth of its potential application. From experience these three criteria have been developed to determine whether an "On-Condition" task is *applicable:*

> The task must detect reduced failure resistance for a specific failure mode.
>
> The task must measure a condition relative to a specific standard (which defines potential failure).
>
> The interval between the occurrence of potential failure and functional failure must be reasonably stable.

The first massive application of "On-Condition" maintenance to a major aircraft system was to hydraulic systems. In 1964 an airline was faced with a requirement for scheduled overhaul of over 100 hydraulic controls and actuators based on its FAA-approved maintenance program — a program that relied on hard time overhauls for all major systems and equipment. Careful study resulted in an alternative "On-Condition" task. The assigned engineers recognized that internal leakage was the *dominant failure* mode. They also discovered that isolation of each subsystem was possible by using the manually operated valves already a part of the airplane's hydraulic system. From there on, it was relatively simple to establish acceptable internal leakage rates for each subsystem and, if leakage was excessive, isolate the faulty units and replace them. This alternative "On-Condition" task resulted in removal of less than 10 percent of the units that would have otherwise been removed, and the reliability of the system did not decrease.

After further experience was obtained, some applications used both pressure decay and internal leakage rates as standards. Later, some applications measured the current draw of the electrically powered auxiliary hydraulic pump as a standard.

Since 1964 many innovative applications of the "On-Condition" process have been devised. Some typical examples are presented later in this handbook.

A COMPARISON OF BENEFITS

How do "On-Condition" tasks measure up?

The applicability of a particular preventive maintenance process depends, of course, on the item's failure modes. If an "On-Condition" task can be devised that meets the previously given criteria*, your first choice should be an "On-Condition" task in preference to "Hard Time". An "On-Condition" task has a number of advantages.

In comparison with a hard time task:

> It measures some condition that is a better predictor of functional failure than time thereby increasing the interval between reworks of each unit. That increased interval decreases logistic costs and decreases the opportunities for maintenance-induced defects.

In comparison with doing no task:

> It causes discovery of potential failures rather than allowing functional failures to occur.
>
> It localizes the requirements for logistic support by discovering these failures at convenient times and locations.

Because of these inherent advantages, there has been continued interest in the development of special systems to measure real time *operating parameters* as a means to discover potential failures. Techniques such as MADARS, the in-flight data system developed for the Air Force C-5A, and other in-flight data acquisition systems, vibration analysis, oil analysis and acoustical analysis are examples. Although conceptually attractive, these techniques have often not provided the benefits predicted for them — usually because they have failed to meet the applicability criteria listed on page 6.

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*See Page 6

It is important, if you are considering such approaches that they be tested impartially and carefully to ensure that they are, in fact, both applicable and effective.

Stated simply, the identification and measurement of some parameter that is, in fact, both highly correlated to a failure mode and reliably measurable in actual service are not easy.

Some non-destructive testing and inspection techniques have, however, been applicable, and very effective means for discovery of potential failures, particularly when applied to engine parts and to structures. Examples of these techniques will be given later.

II. NON-DESTRUCTIVE INSPECTION AND TESTING

The techniques of non-destructive inspection and testing represent major opportunities for the design of applicable and effective "On-Condition" tasks. Since the use of this term varies somewhat, let's identify the processes that are commonly considered as NDI/NDT techniques used in maintenance.

Borescopy and other aids to vision
Liquid Penetrant
X-Ray, Radio-Isotope and Neutron Beam Radiography
Magnetic Particle
Eddy Current
Ultra-Sonic
Acoustics

A considerable body of knowledge has been acquired by specialists in both commercial and military aviation about the application to aircraft maintenance. The Annual NDI/NDT Conference sponsored by the Air Transport Association* is an important source of information dealing with development of new NDI/NDT techniques.

CURRENT COMMERCIAL PRACTICE

Perhaps the most significant characteristic of commercial use of these techniques for aircraft maintenance is their use as part of preventive maintenance programs over a broad range of needs. These techniques are used intensively to discover potential failures thereby preventing the functional failures that in some cases threaten safety, often reduce aircraft availability and always increase operating costs.

A fundamental rule in the application of these techniques is that the selected technique must be validated for each specific

*Air Transport Association of America
1709 New York Ave., N.W.
Washington, D.C.

application. Often this means that a particular technique cannot be effectively applied until specific knowledge about expected defects has been obtained. Or in some cases, lacking specific information, many orientations of the NDI/NDT device are necessary to ensure that all potential defects are detected.

FUTURE OPPORTUNITIES

The principal opportunity for future applications of NDI/NDT to maintenance of Naval aircraft is the development of new, applicable and effective On-Condition preventive maintenance tasks.

You have already been introduced to the three criteria for an applicable "On-Condition" task. Here they are again, for convenience:

> The task must detect reduced failure resistance for a specific failure mode.
>
> The task must measure a condition relative to a specific standard (which defines potential *failure*).
>
> The interval between the occurrence of potential failure and functional failure must be reasonably stable.

Keep these clearly in mind when considering new NDI/NDT preventive maintenance tasks. They clearly define the "applicability" requirement.

The question of effectiveness deals with a different quality. Effectiveness is a measure of results. If functional failure affects safety, a task must reduce the risk of failure to an acceptable level. If failure does not affect safety, you must measure effectiveness in economic terms.

Often in our excitement at discovering a new technique, whatever our assignment, we are prone to getting carried away by the cascade of apparent benefits from this new "horn of plenty" while forgetting the potential pitfalls. If you have any past

experience in the development of NDI/NDT applications, you will surely recall a specific case of this kind. Two prominent gremlins should be dealt with. The first is lack of repeatability, the second is what quality control technicians call "type II" error. These problems generally relate to NDI/NDT applications where some "reading" substitutes for direct visual evidence.

In the first instance, the condition we define as a potential failure must be consistently represented by some specific reading, otherwise both errors of omission and comission will occur.

In the second instance, given acceptable repeatability, we must assure ourselves that our NDI/NDT task does not have a significant "type II" error. These errors are the early or unnecessary removals caused by reacting to the results of an NDI/NDT task when, in fact, failure is *not* imminent. Unfortunately, you cannot evaluate the impact of this kind of error unless you leave the hardware in service to see whether the predicted functional failure occurs. (If you remove all engines that fail to meet your oil analysis standards, you eliminate the opportunity to evaluate the real cost of oil analysis resulting from operating hours lost because of actions taken in response to the results of specific analyses.)

III. APPLICATIONS

This section of the handbook gets down to cases. Before getting down to specific examples, let's generally review two major areas of application, structures and powerplants.

STRUCTURES

The main causes of reduced resistance to failure in structures are fatigue and corrosion. These are both age-related, fatigue to total age (in load cycles) and corrosion to the time since the last corrective action.

An applicable and effective structural inspection plan prevents critical functional failures. It also collects information that helps to reduce the resources required to maintain airworthiness. Such a plan is, in fact, a carefully orchestrated set of "On-Condition" tasks.

The starting point is the identification of structurally significant items (SSIs). An SSI is "a specific structural region that requires scheduled maintenance as part of an RCM program to guard against the fracture of significant elements. The primary consideration in determing structural significance is the effect that failure of an element has on the residual strength of the remaining assembly."* The selection of SSIs must be supported directly by the designer, since he alone is in a position to identify the structural regions which merit selection as SSIs.

The selection of the required tasks and establishing their periodicity is detailed very carefully in a recent book on maintenance program design.* The following procedure is intended only as a summary of that process.

First - Determine whether the SSI's design is damage tolerant or safe life (failure critical, requiring discard at some age limit).

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*See *Reliability-Centered Maintenance.* DoD Report AD-AO 66579

The concept of damage-tolerant design relies upon effective periodic inspection. Damage-tolerant structure is designed to be redundant or is designed so that defects are easily detected and have slow propagation rates. The related standards for the ability of redundant structure to carry loads after the initial failure and the crack propagation rates for single element structure are part of the design specifications.

Safe-life structure has little or no redundancy. Its safety depends upon its replacement at some age based upon its use and its fatigue life or periodic load testing. Safety depends on a combination of periodic inspections for corrosion and accidental damage and repeated load tests or a safe-life discard task.

An aircraft wing can be designed as a damage-tolerant structure. An arresting gear hook is a typical safe-life structure.

Damage tolerant items are rated in decreasing order of impact (1, 2, 3, or 4). The following factors are rated separately:

Reduction in residual strength

Fatigue life

Crack propagation rate

Corrosion susceptibility

Accidental damage susceptibility

Safe-life items are similarly rated. The following factors are rated separately:

Corrosion susceptibility

Accidental damage susceptibility

(It is presumed, for these items, that the life limit for fatigue has already been determined by test.)

Second - Use these ratings to assign a class number.

The lowest rating for any of the applicable factors assigned to a specific item is designated as the class number for that item. This class number is the basis for the initial inspection interval.

There is no "rule" for establishing these inspection intervals.

For damage-tolerant structure, in commercial practice, it is common to use the class number directly to determine the initial inspection interval. This interval is expressed as a fraction of the fatigue life design goal.* These intervals are only a small fraction of the expected life, so there are many inspections of the most critical items before the expected life is attained. The Naval Air Systems Command has undertaken an effort to devise a more vigorous method of determining inspection intervals, using fracture mechanics theory. However, a useful procedure is some time away.

For class 1 and class 2 items, inspection of all items on all aircraft is desirable. When some confidence has been obtained based on the absence of problems at the first several sequential inspections of early aircraft it is not unusual to eliminate the first several sequential inspections on subsequent aircraft.

For class 3 and 4 items, it is usual to establish total-time-based fleet leader sampling after some initial experience has been obtained. See Figure 2.

For safe-life structure, a life limit based on design fatigue life has already been established. Therefore the primary purpose of the structural inspection plan is to prevent failures resulting from corrosion and accidental damage. There is no cohesive method in commercial practice for establishing inspection intervals for safe-life structure. The class number, of course provides a very useful relative measure that can assist you in assigning these intervals, provided you have additional knowledge about the specific operating environment. You should, after setting conservative initial

*See page 245, *Reliability-Centered Maintenance*, DoD Report AD-A066579 for additional details.

FIGURE 2

A TYPICAL INITIAL DAMAGE-TOLERANT STRUCTURES INSPECTION PLAN

OVERHAUL VISIT	1	2	3	4	5	6	7	8	9	10	11	....
CONTINUOUS SAMPLING INSPECTIONS (APPLICABLE TO AIRCRAFT NOS. 1-10 — CLASS 3 & 4 ITEMS)			1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	....
			1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	....
			1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	....
			1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	....
			1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	....
100 % INSPECTIONS (APPLICABLE TO AIRCRAFT NOS. 11 AND ABOVE — CLASS 1 & 2 ITEMS)	—	—	1	1	1	1	1	1	1	1	1	....
100% INSPECTIONS (APPLICABLE TO AIRCRAFT NOS. 1-10 — ALL ITEMS)	1	1	1	1	1	1	1	1	1	1	1	....

FATIGUE LIFE

0 OPERATING HOURS/LANDINGS

intervals that are consistent with the designated class numbers, raise these on the basis of operating experience.

The intervals used for structural inspection tasks may be measured in operating hours, landings, or calendar time.*

In many cases these measures may be tightly correlated; then any one can be used universally. In a specific military environment *these measures may be very loosely correlated*, if at all. As a result you may find it necessary to apply a different measure for different kinds of failure. (In some cases after determining intervals based on the best parameter, you may find that it is possible, by over-scheduling some tasks to convert to a common measure for several kinds of tasks.)

POWERPLANTS

"On-Condition" tasks can be applied to powerplant items in two ways. They can be done on installed engines, either by external visual inspections, internal borescope inspections or radiography at assigned intervals. They can also be done during engine shop visits either on assembled engines or on parts after disassembly. Rather than having a specific periodicity, parts are often assigned a range of times during which a specific inspection is required. This approach permits so-called "opportunity inspections". These make it practicable to acquire information about the effect of age on the condition of parts from engines normally flowing through the shop, rather than forcing many removals to obtain the same information. Of course, if an engine type is highly reliable and does not provide such opportunities, a maximum age limit for some parts may be imposed in order to acquire the desired information. Such limits will force specific engine removals.

The ability to design applicable and effective "On-Condition" tasks for an assembled powerplant depends to a great degree on

*Fatigue life or crack inspection intervals may in some cases be stated in terms of cumulative G loading.

the provisions made by the designers of the powerplant and the powerplant installation for access. Modern commercial jet engines provide many openings in the case for insertion of a borescope and access to the core of the engine at the inlet that permits the insertion of a probe containing a radio-isotope. (Here are two powerful examples of adapting design to increase the utility of state-of-the-art maintenance technology which every designer should strive to emulate in his own field.)

These techniques are extremely effective bases for preventive tasks. Also, knowledge about an engine's design often proves useful when selecting such tasks. For example, if it is known that bowing of the nozzle guide vanes will always cause the exhaust gas temperature (EGT) to reach its limit before they rub the turbine blades, then a radiographic inspection is not an effective task.

"On-Condition" tasks for powerplants are, of course, not limited to the use of borescopes and radiography. Perhaps the most useful, simple tasks are those requiring periodic examination of oil screens or filters. The best tasks of this kind require examination of the material found in the screen or filter to determine further action, otherwise these tasks can trigger unnecessary engine removals.

If, for example, the first removal of a screen after a previous engine failure reveals a small amount of metal particles, they may be residual material from the previous failure. In this case, cleaning the screen and removing it again after a few hours operation will determine whether a new failure has occurred. It is practicable, for a specific engine type, to accumulate knowledge about the size, shape and kind of particles found in screens for the purpose of establishing condition standards that allow continued operations where, previously, any material found in screens was cause for engine removal.

For fuel system filters, tasks requiring ΔP indicator checks can be much more informative, if they require that the removed filters be examined.

NOTE

Effective use of the information obtained from "On-Condition" tasks performed on engine parts is greatly increased if there is a historical record of the life history of such parts. The cost of maintaining such records at a serial number level limits this practice to those parts which are the cause of high costs or high safety risks rather than attempting to maintain such records on all parts.

EXAMPLES

Anyone considering the application of these ideas without some previous experience should, by now, be thirsty for some examples. You probably already have some potential applications in mind. Because of the wide range of possibilities, you would be lucky, indeed, if one of the examples that follow exactly meets your needs. Nevertheless, you should get some good pointers.

This section of the handbook presents a number of examples in 6 different categories:

1. Visual inspection of hardware
2. Visual inspection of fluid level or condition
3. Wear measurement
4. Temperature measurement
5. Pressure measurement
6. NDT/NDI

NOTE

This set of examples does not include an application of an "On-Condition" task to avionics systems. Commercial air transport avionics systems design provides a high level of redundancy in critical avionics functions, so individual equipment failures are not often critical. In military avionics systems some "On-Condition" tasks may be both applicable and effective because of safety or mission criticality and lack of redundancy. The challenge to you is to find tasks that meet the criteria previously described.

These examples are taken directly from commercial air transport practice. They may not be specifically applicable to any Naval aircraft, nor are the inspection intervals likely to be directly applicable. They are provided solely to give you a feel for current applications of "On-Condition" tasks. Measuring applicability and effectiveness requires that you "go find out - GFO". It is absolutely impracticable to require that a mechanic provide an analyst with all information he might need about everything he does. It is practicable to require the limited information needed to identify and rank problems. You can have your most stimulating experiences when you "GFO".

EXAMPLE 1

VISUAL INSPECTION - HARDWARE

ON-CONDITION TASK

ITEM: Gas turbine engine
Turbine mid-frame liner

TASK: Visually check mid-frame liner using a borescope.

FREQUENCY: Part TT* $<$ 4000 hours - not required

Part TT* $\geq$ 4000 hours - "B" check

STANDARD: The following limits apply:

Cracks (other than those progressed to aft edge)	Any number permissible, provided they are not greater than 6 inches long and separated by at least 6 inches. Cracks 6-9 inches require reinspection at 250 hours. No cracks $>$ 9 inches permissible.
Cracks to aft edge	Any number permissible, provided they are not greater than 6 inches long, separated by at least 6 inches and do not "Y" out to allow a piece larger than 1 square inch to break off.
Cracks at front edge	None allowed.
Missing rivets	None allowed.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-ZZ

* - "TT" "total time since new"

EXAMPLE 2

VISUAL INSPECTION - HARDWARE

ON-CONDITION TASK

ITEM: Gas turbine
Engine combustion liner assembly

TASK: Visually check all combustion liner assemblies using a standard borescope.

FREQUENCY: Part TT $<$ 2000 hours - not required

Part TT $\geq$ 2000 hours - 750 hours

STANDARD: *The following limits apply:*

All surfaces	
carbon accumulation discoloration	Serviceable - any amount
Riveted joints	
loose or cracked rivets	Not more than X rivets in each circle failed or missing
cracked or torn rivet holes in cowl or skirt	1 crack to edge; 20 holes per circle
Dome assembly	
distortions of swirl cup trumpets	Serviceable - any amount
swirl cup and trumpet cracks	Serviceable - any amount

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX and Engine Shop Manual

EXAMPLE 3

VISUAL INSPECTION - HARDWARE

ON-CONDITION TASK

ITEM: Gas turbine engine
First stage compressor rotor blades

TASK: Visually check compressor rotor using a borescope

FREQUENCY: Part TT $<$7000 hours since new - not required

Part TT 7000-10,000 hours since new - 1000 hours

Part TT $>$10,000 hours since new - 500 hours

STANDARD:

Blades	
cracks	Not serviceable
general damage	Any amount not more than .OOX inch deep (no tears, breaks through blade, or distortion)
damage on airfoil surface	Any amount provided it is not more than .OOX inch deep and a transverse line is not formed than may later crack; damage is .Z inch from LE or TE.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-YY

EXAMPLE 4

VISUAL INSPECTION - HARDWARE

ON-CONDITION TASK

ITEM: Aircraft wing structure, rear spar, zone XAB/YAB

TASK: Inspect rear spar at bulkhead intersection for fatigue cracks

FREQUENCY: 10,000 hours

STANDARD:

Inspect as seen from gear well, cleaning as necessary and using a flashlight and 10X glass. aircraft may not be operated with any crack. Repair or replacement required. Refer to Engineering.

FOR ADDITIONAL INFORMATION SEE:

Structural inspection document A-1234

EXAMPLE 5

VISUAL INSPECTION - HARDWARE (DYE PENETRANT)

ON-CONDITION TASK

ITEM: Gas turbine engine compressor rear frame.

TASK: Visually check front flange for cracks. Use dye penetrant if a crack is suspected.

FREQUENCY: 500 cycles (flights)

STANDARD: The following limits apply:

Flanges cracked outwards of the bolt hole	No action
Flanges cracked inwards of bolt hole - not turned axial	Reinspect within 250 cycles
Flanges cracked inwards of bolt hole - turned axial	Install doubler within 100 cycles

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX

EXAMPLE 6

VISUAL INSPECTION - FLUID LEVEL OR CONDITION

ON-CONDITION TASK

ITEM: AC generator constant speed drive - oil level and condition.

TASK: Check CSD oil condition
Check CSD oil level

FREQUENCY: "A" check (approx. weekly)

STANDARD: The following limits apply:

Oil red, brown, cloudy or smells burnt	Change oil per MM
Oil below top of green band	Replenish
Oil at bottom of yellow band or below	Comply with special instructions in MM 24XX

FOR ADDITIONAL INFORMATION SEE:

OOX-OY-OZ-AB

EXAMPLE 7

WEAR MEASUREMENT

ON-CONDITION TASK

ITEM: Landing gear brakes

TASK: Check brake wear

FREQUENCY: #2 Service (daily)

STANDARD:

Wear indicator pin	Extension $<$ 9/16" - replace brake

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 32-XX

EXAMPLE 8

WEAR MEASUREMENT

ON-CONDITION TASK

ITEM: Horizontal stabilizer drive chain

TASK: Check drive chain wear

FREQUENCY: 4500 hours

STANDARD:

16 roller span   Replace if measurement exceeds 11-7/8"

FOR ADDITIONAL INFORMATION SEE:

Measure across span of 16 rollers from outside of first to outside of 16th roller.

EXAMPLE 9

TEMPERATURE MEASUREMENT

ON-CONDITION TASK

ITEM: Gas turbine engine #3 bearing compartment

TASK: Measure #3 bearing compartment breather temperature margin

FREQUENCY: 1000 hours*

STANDARD:

Breather temperature margin	Must be positive at both check points.
	Difference between check points must not exceed 5°C.

*Repeat at 500 hours if margin 5-10°C.
Repeat at 200 hours if margin <5°C.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX

EXAMPLE 10

PRESSURE MEASUREMENT

ON-CONDITION TASK

ITEM: Hydraulic system

TASK: Check subsystems 1, 2, &3 for internal leakage

FREQUENCY: 3000 hours

STANDARD:

	Aux pump pressure #3 (ISOL light off) >2800 PSI
c-a	Pressure differential (ISOL light on) <100 PSI
e-c	Pressure differential (1-3 RMP - on) <300 PSI
h-c	Pressure differential (2-3 RMP - on) <300 PSI

If system does not meet standard, use flowmeter and isolation valves to isolate source of leakage.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 29-KK

EXAMPLE 11

PRESSURE MEASUREMENT

ON-CONDITION TASK

ITEM: Pneumatic system

TASK: Pneumatic system pressure decay check

FREQUENCY: "B" check (approx. monthly)

STANDARD:

Total system leakage	15 PSI/min
#2 manifold leakage	5 PSI/min

FOR ADDITIONAL INFORMATION SEE:

Job card XXX - YY - ZZ

EXAMPLE 12

PRESSURE MEASUREMENT

ON-CONDITION TASK

ITEM: Cabin positive pressure relief valve

TASK: Functionally test cabin positive pressure relief valve

FREQUENCY: 8000 hours

STANDARD:

Relief valve opening p.s.i.	8.70 - 8.95 PSIG with .5 PSIG Δ p at static ports.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 21-YY

EXAMPLE 13

NDT/NDI - RADIOISOTOPE

ON-CONDITION TASK

ITEM: Turbine nozzle outer case

TASK: Isotope inspect for missing 3rd stage NGV retaining lugs

FREQUENCY: 1000 hours

STANDARD: The following limits apply:

Lugs Missing	Action
0	Reinspect, 1000 hours
1	Reinspect, 100 hours
2, 3	Reinspect, 50 hours
4 or more	Remove immediately

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX

EXAMPLE 14

NDT/NDI - RADIOISOTOPE

ON-CONDITION TASK

ITEM: Combustion chamber outer front case

TASK: Isotope check fuel nozzle flange-to-can clearance

FREQUENCY: 3500 hours (initial)
1500 hours (repeat)

STANDARD: The following limits apply:

Can/Nozzle Clearance	Action
$\leq$.250"	Reinspect, 1500 hours
>.250 to .300"	Borescope, 250 hours
>.300 to.500"	Borescope, 50 hours
>.500"	Repair immediately

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX

EXAMPLE 15

NDT/ADI - RADIOISOTOPE

ON-CONDITION TASK

ITEM: First stage nozzle guide vanes

TASK: Isotope inspect NGV clearance

FREQUENCY: 3000 hours

STANDARD:

Clearance	Action
< 3/16" (or any rub)	Remove from service
3/16 - 1/4"	Reinspect, 50 hours
1/4 - 5/16"	Reinspect, 275 hours
5/16 - 7/16"	Reinspect, 450 hours
7/16 - 21/32"	Reinspect, 1200 hours
> 21/32"	Reinspect, 3000 hours

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-XX

EXAMPLE 16

NDT/NDI - ULTRASONIC

ON-CONDITION TASK

ITEM: Compressor rotor spool, Stage 11-13

TASK: Ultrasonic inspect stage 13 bolt holes for cracks.

FREQUENCY:

Last Inspection	Cycles
Topcase bubbler	1800
Borescope hole - ultrasonic	700

STANDARD: No cracks permissible

FOR ADDITIONAL INFORMATION SEE:

EXAMPLE 17

NDI/NDT - EDDY CURRENT

ON-CONDITION TASK

ITEM: Front compressor rear hub

TASK: Eddy current inspect the #2 hub

FREQUENCY: As required by current reliability program

STANDARD: No crack indications permissible.

FOR ADDITIONAL INFORMATION SEE:

Maintenance Manual 72-YY

EXAMPLE 18

NDI/NDT - EDDY CURRENT

ON-CONDITION TASK

ITEM: Front compressor disk, stage 7

TASK: Eddy current inspect 7th stage disk for cracks

FREQUENCY: 2200 cycles (initial)
1200 cycles (repeat)

STANDARD: No crack indications permissible.

FOR ADDITIONAL INFORMATION SEE:

IV. DESIGNING AN "ON-CONDITION" TASK AND MEASURING RESULTS

We've discussed "what" and "why", now you're probably wondering about "how" and "when". In this section, the handbook will discuss designing an "On-Condition" task, both generally and specifically. Then the problem of evaluating effectiveness will be discussed to help you look backward at a particular task and decide whether it's doing the job you intended.

DESIGNING AN "ON-CONDITION" TASK

We have established that "On-Condition" tasks are applicable when the following criteria are met:

We can detect reduced failure resistance for a specific failure mode.

We can define a specific standard which is the basis for determining whether a potential failure exists.

The relationship between the age at which potential failures occur and the age at function failure is reasonably constant.

Designing an "On-Condition" task requires the following steps:

Identify a specific, dominant failure mode.

Determine whether its occurrence is preceded by something you can either measure or see, smell, hear or feel. This "something" may be a physical dimension (tire tread depth, crack length, turbine blade clearance), some operational dimension (landing gear retraction time, hydraulic fluid leakage rate, breather pressure, vibration amplitude, voltage drop), or some unique quality like a change in color, odor or the occurrence of some special sound.

Collect data to establish how the dimension or quality that you have selected behaves before actual functional failure occurs. (Assure yourself that the third criterion for an applicable "On-Condition" task can be met.)

If the failure mode you have selected is not related to a critical failure, you can collect data from real operating experience as was done in the example that follows. (Note that failure in this case is wear beyond the permissible retread limit, not collapse of the tire, so safety was not involved in acquiring the needed wear information.)

If the failure you have selected is a critical failure, and you desire to maximize the effectiveness of the desired "On-Condition" task, some sort of special testing or review of design data and the results of previous testing will be required.

Select a standard based on experience, tests or design data.

Establish an inspection or testing interval that gives the desired level of effectiveness. Remember that if you base this interval on average rates of degradation you will not prevent all failures.

Let's apply these steps to a specific example:

Required: An "On-Condition" task that removes tires before they are worn to the retread wear limit but maximizes tread life.

1. The dominant failure mode is carcass damage that prevents retreading.

2. Its occurrence is preceded by progressive decrease in the tread depth during use. The retread limit is indicated by wear indicators built into the tire during manufacture.

3. A sample of the data collected from operations to measure tire wear characteristics is shown in Figure 3. In this case, 20% of the airplanes were randomly selected and one tire life was tracked for each position on each sample airplane. About 4 months were required to acquire the data. The results were charted in Figure 4. The best, worst, and average performance curves are based on the best, worst and average tread depths at each biweekly inspection.

4. Zero tread depth at any point on a tire was defined as the standard. Worst tire performance showed an interval of 12 landings between the standard and the retread limit.

5. Since it was very unlikely that more than 12 landings would occur between #2 Services, inspections at his interval (30 hours) gave a high confidence that functional failures would not occur and tire changes would not be required at enroute stations.

NOTE

If cumulative landings were used as a parameter for hard time control of tire removals, let us see what would result. Such a task, in order to give the same level of protection from functional failure as the "On-Condition" task would have to require tire removal at or before 210 landings. The "On-Condition" task would occur, on the average, at 261 landings, providing an average increase of at least 51 landings per tire, a 24% increase in life with no increase in risk.

The end product of this process is represented for a typical task, "Check main and nose gear tires for wear" in Figure 5. This is a typical task that relies on a simple visual inspection.

The key to establishing an appropriate task interval is the acquisition of information about the rate at which failure resistance decreases and at what age functional failure occurs.

FIGURE 3

MLG TIRE TREAD WEAR DATA

A/C TAIL NO.	TIRE POS.	INST. DATE	LANDINGS	1	2	3	4	5	6	7	8	9	REM. DATE	LANDINGS	RSN
	1	4/23	1423	14	13	9	2						6/25	1658	RTL
U 42	2	3/10	1267	15	13	11	7	-4					5/21	1557	RTL
	3	2/28	1215	15	12								3/31	1327	TS
	4	1/2	990	14	13	NR	10	7	1				4/1	1330	RTL
	5	3/16	1247	14	13	10	5						5/23	1498	ZT
	6	12/30	981	15	14	13	10	7	1				3/26	1301	ZT
	7	2/13	1163	13	12	11	9	3					5/7	1473	RTL
	8	2/13	1163	15	13	9	0						4/10	1371	ZT
	1	1/4	801	14	12	9	1	-1							
U 47	2	1/4	801	14	12	11	9	8	-4						
	3	3/15	1061	15	14	10	9	5							
	4	12/24	775	15	13	12	10								
	5	2/13	957	16	15	13									
	6	2/13	957	14	13										
	7	3/25	1113	13	11										
	8	4/2	1139	13											
	1	2/3	407												
U 50	2														

Columns 1–9: MIN. TREAD DEPTH-BI-WEEKLY INSP. (1/32)"

REASON CODE	
RTL	RETREAD LIMIT
TS	TREAD SEPARATION
ZT	ZERO TREAD
OT	OTHER

FIGURE 4

DETERMINING ON-CONDITION INSPECTION INTERVAL FOR AIRCRAFT TIRES

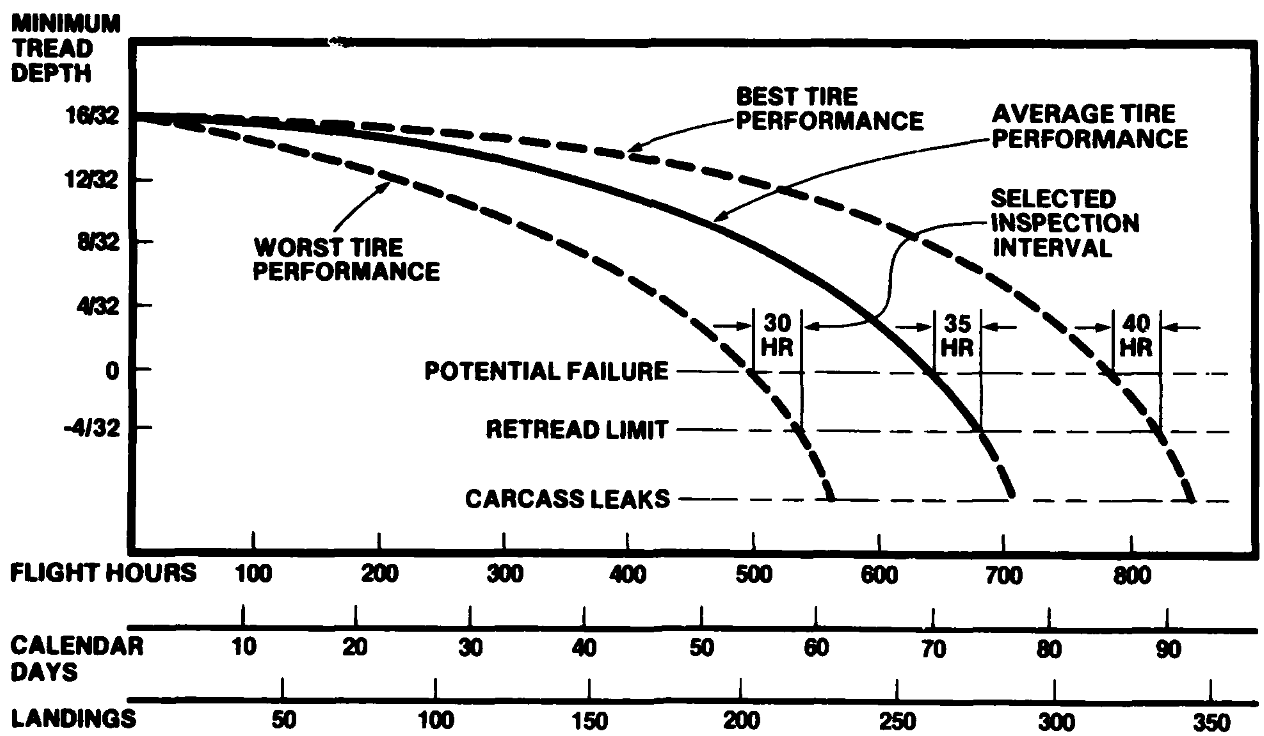

FIGURE 5

ON-CONDITION MAINTENANCE CRITERIA

ON-CONDITION TASK

SYSTEM: Landing Gear

SUBSYSTEM: Tires

FREQUENCY: #2 Service (30 hours)

TASK: Check main and nose gear tires for wear

STANDARD:

Any tire worn so that the tread pattern at any spot is worn away must be replaced.

OBJECTIVE:

Avoid wear that prevents carcass retreading (an economically defined functional failure)

FOR ADDITIONAL INFORMATION SEE:

In the case of structures inspections, sampling techniques that compare the condition of the same items on several aircraft with some standard by scheduling a pattern of repeated inspections as the structure ages are used very effectively. In such cases, if a potential failure is discovered, a typical action would be to reinspect all of the items in service. Usually, a reinforcement of some kind would then be installed, or 100% repeated intensive inspections would be required.

It may seem attractive in some applications to consider a different initial interval (time before first inspection) from the interval for later, repeated inspections. This approach, although intuitively attractive, is rather difficult to administer, except in the case of structures inspections where the "total time" measurement is continous. Applying this approach to powerplants may be practicable, provided there is an accurate cumulative time record for individual parts by serial number.

MEASURING RESULTS

Perhaps the most rewarding attribute of an "On-Condition" task is that, by reviewing failure information you can get an immediate evaluation of its applicability. This evaluation does not immediately assure the analyst that there is not a more effective task, but it does tell whether the task is having a favorable effect on functional failures. All one has to do is find out whether the affected hardware received in the shop for repair has been found unacceptable because of the "On-Condition" standard or has actually failed (functional failure). If a large number of functional failures have occurred, the task is clearly not applicable and either its periodicity must be decreased, its standard should be adjusted, or it should be deleted.

Effectiveness, if the failure adversely affects safety, can be evaluated by finding whether the risk of failure (failure rate) has been reduced to an acceptable level. If safety is not involved, an economic trade-off similar to that described in Section 4.4 of DoD Report AD-AO66579, *Reliability - Centered Maintenance* is required.

One thing you can do today to increase the efficiency of any preventive maintenance program is to test each *existing* "On-Condition" task against the criteria in this handbook. Then take action to eliminate or change those tasks that fail to meet the requirements for applicability and effectiveness.

Give it a try. Chances are that you will discover a real opportunity to help the Navy to do its job more effectively — and you will learn some things that will improve your own effectiveness, too.

V. GLOSSARY

age - The measure of a unit's total exposure to stress since some previous, specific event.

applicable task - A task that prevents or reduces the impact of failures. (See effective task)

critical failure - Loss of function or secondary damage that could have a direct, adverse effect on operating safety.

damage-tolerant structure - Residual strength enables structure to withstand specified loads after failure of a significant element; also called "fail-safe". (See safe-life structure)

effective task - A task that achieves the required level of failure risk (for critical failures) or of cost effectiveness (for non-critical failures).

fail-safe structure - See damage tolerant structure.

failure finding task - A task to find functional failures of hidden functions.

functional failure - Failure of an item to function within specified limits.

hard time task - A task performed regularly after the accumulation of a specified time or number of operating events without reference to material condition.

hidden function - A function whose failure will not be evident to the operating crew during performance of their normal duties.

on condition task - A task performed to detect potential failures.

opportunity inspection - An inspection made possible by an unrelated disassembly of a unit, usually for repair.

potential failure - Failure to meet a pre-established condition or performance standard that closely precedes functional failure.

structurally significant item - A specific site or region of structure or a structural element whose failure would result in a material reduction in residual strength of functional failure.

TSO - Time since overhaul (or since new for a unit not yet overhauled).

TT - Total time since new.

type II error - An error of commission-unnecessary or premature action taken in response to a specific criterion.